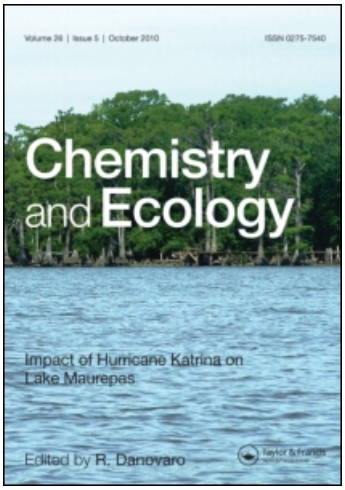

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WATER DISCOLORATION IN ALEXANDRIA, EGYPT, APRIL 1993. I. OCCURRENCE OF PROROCENTRUM TRIESTINUM SCHIFFER (RED TIDE) BLOOM AND ASSOCIATED PHYSICAL AND CHEMICAL CONDITIONS

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A yellow-brown coloration of water developed in the Eastern Harbour of Alexandria (Egypt) during April 1993. The dinoflagellate *Prorocentrum triestinum*, the causative organism, culminated in a population peak of $71 \cdot 10^6$ cells l^{-1}, chlorophyll *a* nearly 361 $\mu g\, l^{-1}$. The bloom occurred with a thermo-haline stratified water column and low surface nutrient levels. Water temperature was considered a crucial environmental factor controlling the occurrence of *P. triestinum* and nitrate was significantly correlated with its counts. The high relative growth constant (3.4 d^{-1}), calculated just prior to the massive occurrence of the species, explains the rapid development of the bloom. A comparison with the earlier phytoplankton studies in the harbour is made.

KEY WORDS: Red tide, thermo-haline stratisfication, growth, *Prorocentrum*.

INTRODUCTION

Almost 35 years ago, large scale red tides began to be reported in the Eastern Harbour of Alexandria (Halim, 1960). This semi-enclosed, highly eutrophic marine basin is located in the central part of the Egyptian Mediterranean coast, cover an area of about 2.8 km^2 (average depth 6 m). The progressive eutrophication in the harbour, induced by the large input of the drainage water and, by implication the stratification of the water, seems to accelerate development of phytoplankton blooms. The major red tide species are *Alexandrium minutum*, *Prorocentrum triestinum*, *P. minutum*, and *Skeletonema costatum* (Halim, 1960; Sultan, 1975; Zaghloul & Halim, 1992; Labib, 1994 a,b).

The data presented here were derived from samples collected in the Eastern Harbour in spring 1993 to elucidate the physical and chemical conditions of the water accompanying the occurrence of the red tide species, *Prorocentrum triestinum*. Factors affecting its occurrence in the harbour, the development of the bloom and the comparison with the earlier ecological phytoplankton studies in the harbour are discussed. Such information has not been previously reported.

The factors controlling the dissipation of the bloom were reported in another paper (Labib & Hussein, 1994).

MATERIAL AND METHODS

The sampling station, to the west of the harbour at 5 m depth, was operated for four weeks between 12 March and 11 April 1993. Surface water temperature and counts of *P. triestinum* were determined at almost daily intervals from 12 March to 1 April. The daily measurements untill 11 April included surface and above bottom water temperature, salinity, dissolved oxygen and the concentrations of chlorophyll *a* (hereafter chl. *a*) and inorganic nitrate, nitrite, phosphate, silicate and ammonia. This latter was determined on 3 April only. Salinity was measured by a Beckman Induction Salinometer and oxygen by Winkler method. (For oxygen, the value are in the range: ± 0.002 ml l^{-1}, precision is 0.7 ml l^{-1}.) Chlorophyll samples were filtered through glass fibre filters and the pigment extracted in 90% acetone. Nutrient samples were filtered and kept frozen until analysis. Chlorophyll *a* and nutrient contents were analyzed following Strickland & Parsons (1972). The values are in the range: ± 0.26 $\mu g\, l^{-1}$, precision is 5 $\mu g\, l^{-1}$ for chlorophyll *a*; range $\pm 0.5\, \mu mol\, l^{-1}$; precision 20 $\mu mol\, l^{-1}$ for nitrate; range $\pm 0.032\, \mu mol\, l^{-1}$, precision 1 $\mu mol\, l^{-1}$ for nitrite; range ± 0.03 $\mu mol\, l^{-1}$, precision 3 $\mu mol\, l^{-1}$ for phosphate; range ± 0.25 $\mu mol\, l^{-1}$, precision 10 $\mu mol\, l^{-1}$ for silicate; and range ± 0.15 $\mu mol\, l^{-1}$, precision 3 $\mu mol\, l^{-1}$ for ammonia.

The phytoplankton samples collected at the surface were first examined for indentification under a research microscope, then preserved by the addition of Lugol's solution. The settling method for counting was used (Ultermöhl, 1958). Duplicated samples were examined and the standard error calculated (36%, $p < 0.1$, Anova test). The correlations between the algal abundance and physical and chemical parameters were also calculated.

Figure 1 shows the study area and location of the sampling station.

RESULTS

The physical and chemical parameters measured at the surface and above the bottom are given in Table I.

Physical Conditions

During March the surface water temperature exhibited a wide variation (16.2–17.9°C). The period between 3 and 11 April showed the surface water to be always warmer and less saline than that at the bottom. With the onset of the bloom on 3 April the surface temperature and salinity were relatively low (18.8°C and 37.3‰, respectively). There was a gradual temperature increase, as days went by, except on 7 April and salinity reached a minimum on 8 April (35.3‰). The water column was stratified, with highest differences in temperature (2.4°C) and salinity (3.2‰) between surface and above bottom on 6 and 8 April. The mixed condition on 11 April was forced by wind action reducing the differences to 0.6°C and 0.15‰.

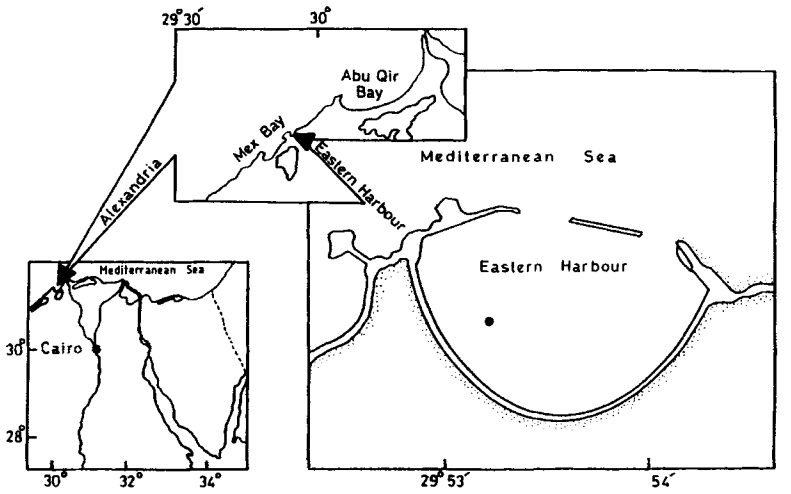

Figure 1 The Eastern Harbour of Alexandria and location of the sampling station (●).

Table I Physicochemical parameters measured in the Eastern Harbour of Alexandria between 3 and 11 April 1993.

Parameter	*April*	*Days*							
		3	*4*	*5*	*6*	*7*	*8*	*10*	*11*
Temperature	Surface	18.8	19.0	19.8	19.9	18.3	19.0	19.6	19.0
(°C)	Bottom	18.1	18.0	18.3	17.5	17.5	17.5	18.5	18.4
Salinity	Surface	37.3	37.0	38.0	35.5	38.6	37.3	36.8	38.9
(%)	Bottom	38.1	37.5	38.6	38.5	39.0	38.5	38.5	39.0
Nitrate	Surface	4.8	3.5	1.8	1.0	3.8	0.65	1.6	3.2
(μmol l^{-1})	Bottom	7.5	6.8	3.5	3.0	4.1	1.80	5.0	6.1
Nitrite	Surface	1.5	1.0	0.45	0.65	0.60	0.25	0.45	0.60
(μmol l^{-1})	Bottom	2.0	2.3	0.55	0.85	0.75	0.40	0.80	1.10
Phosphate	Surface	3.8	3.5	1.80	0.35	4.80	2.50	6.85	2.50
(μmol l^{-1})	Bottom	4.6	4.3	3.80	5.50	5.50	3.60	7.60	5.58
Silicate	Surface	4.5	6.8	8.0	6.30	8.35	5.60	6.30	5.80
(μmol l^{-1})	Bottom	8.4	8.6	8.5	6.80	8.55	6.30	7.10	6.80
Ammonia	Surface	2.1	–	–	–	–	–	–	–
(μmol l^{-1})	Bottom	6.5	–	–	–	–	–	–	–

(–) not measured.

Chemical Conditions

Nutrient concentrations are governed by the input of the drainage water, mixing with the adjacent neritic Mediterranean waters and consumption by the algal bloom; the bloom commenced with nutrient concentrations of 4.8 (nitrate), 1.5 (nitrite), 3.8 (phosphate), 4.5 (silicate) and 2.1 (ammonia) μmol l^{-1}. There was severe

impoverishment of nutrients with the progressive development of the bloom, nitrate falling dramatically to 0.65 $\mu mol\,l^{-1}$ on 8 April, coinciding with the bloom peak. Phosphate was almost zero on 6 April (0.35 $\mu mol\,l^{-1}$). Silicate, as expected, showed no significant variations, with a maximum (9.6 $\mu mol\,l^{-1}$) at the bloom peak. The nutrient concentrations above the bottom were much higher than in the surface water, nitrate by 1.5–3 times, phosphate by 1.1–15.7 times and ammonia by 3 times.

Description of the Bloom

The surface concentrations of *P. triestinum*, chlorophyll *a* and oxygen are shown in Figure 2. During March the population denstity of *Prorocentrum triestinum* never exceeded $11 \cdot 10^3$ cells l^{-1}. By 1 April, this species represented an active component of the community ($19 \cdot 10^3$ cells l^{-1}, 35‰ of the total algal counts). The green to yellow surface colour became visible on the following day with *P. triestinum* $125 \cdot 10^3$ cells l^{-1}, Chl. *a* 6.2 $\mu g\,l^{-1}$. The development of the bloom was very rapid, the water becoming yellow-brown on 3 April, with $4 \cdot 10^6$ cells l^{-1}, Chl. *a* 19.3 $\mu g\,l^{-1}$, oxygen 7.8 $ml\,l^{-1}$. A reddish water was seen to cover most of the harbour between 4 and 11 April, *P. triestinum* then contributing 91.6–99.6% of the total algal numbers. Its density in the period 4–6 April fluctuated between nearly $19 \cdot 10^6$ cells l^{-1}, Chl. *a*

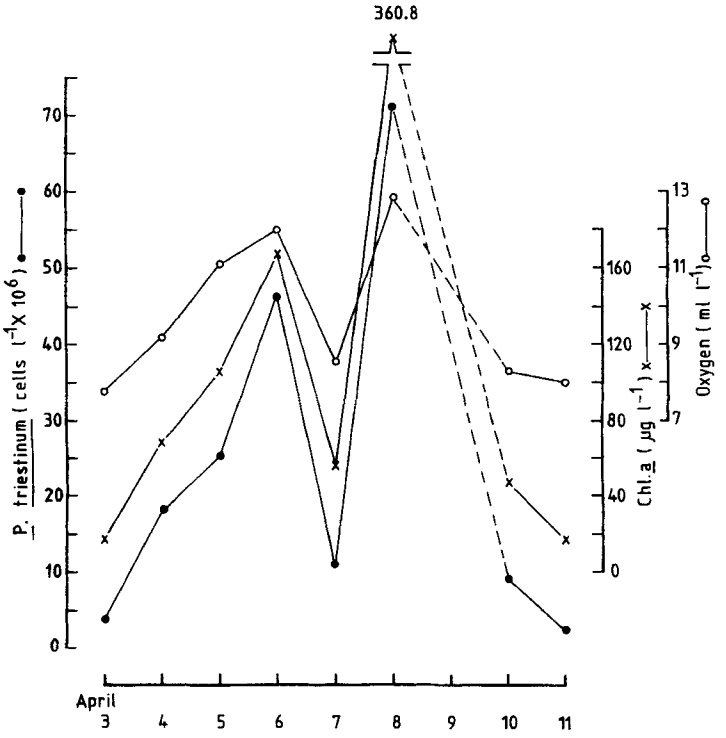

Figure 2 Surface concentrations of *Prorocentrum triestinum* (●–●) Chlorophyll *a* content (*x*–*x*) and dissolved Oxygen (○—○) in the Eastern Harbour of Alexandria during the period from 3 to 11 April 1993. (– – – –) a missed day.

67 μg l^{-1}, oxygen 9.2 ml l^{-1} and $46 \cdot 10^6$ cells l^{-1}, Chl. *a* about 168 μg l^{-1}, oxygen 12 ml l^{-1}. However, the decreased temperature on 7 April (18.3°C), and subsequently the smaller differential between surface bottom temperatures (0.8°C) and the south-east wind (3.5 m s^{-1}), probably affected the population, *P. triestinum* dropping to $11 \cdot 10^6$ cells l^{-1}, Chl. *a* 58.5 μg l^{-1}, oxygen 8.5 ml l^{-1}. A bloom peak was then recorded on 8 April ($71 \cdot 10^6$ cells l^{-1}), raising Chl. *a* to a maximum of 360.8 μg l^{-1} and oxygen to 12.8 ml l^{-1}. Other phytoplankton species within the bloom period are given in Table II. The bloom started to dissipate partially on 11 April, when *P. triestinum* declined sharply to $2.6 \cdot 10^6$ cells l^{-1}; it was no longer visible on the following day ($60 \cdot 10^3$ cells l^{-1}). The community then changed, and the centric diatom, *Chaetoceros affine*, became dominant on 15 April ($620 \cdot 10^3$ cells l^{-1}, 62% of the total algal counts), followed by *Protoperidinium diabolus* ($102 \cdot 10^3$ cells l^{-1}).

DISCUSSION

Prorocentrum triestinum is well known red tide species in temperate coastal waters and its occurrence is closely linked to land drainage (Iizuka, 1976). The recent ecological phytoplankton studies (Labib, 1994 a,b), based on short term sampling in the Eastern Harbour during 1991, revealed the dominance of *Prorocentrum minimum* in April and *Pyramimonas* sp. early May, with a surface water temperature of 20.5 to 22.8°C, a salinity 37.3 to 38.8‰, a density stratified water column and low nitrate and phosphate concentrations (0.44–0.55 μmol l^{-1} and 1.1–1.58 μmol l^{-1}, respectively). *Prorocentrum triestinum* contributed a maximum population size at $158 \cdot 10^3$ cells l^{-1} on 11 May. This species represented a major element of the multi-species red tide blooms during summer and autumn, culminating in two population peaks of $9 \cdot 10^6$ and $7.5 \cdot 10^6$ cells l^{-1} on 7 and 18 July, with a surface temperature of 27.3–27.7°C, a salinity around 36.5‰, a density stratified water column within 1.2–2.5°C and 0.6–1.3‰ and low nitrate (1.2–1.8 μmol l^{-1}). Again in late

Table II Phytoplankton species, including *Prorocentrum triestinum* (10^3 cells l^{-1}), recorded in the Eastern Harbour of Alexandria during 4 and 11 April 1993.

April	*Days*						
	4	*5*	*6*	*7*	*8*	*10*	*11*
Bacillariophycea							
Chaetoceros curvisetum	–	3.3	115.6	289.0	30.8	–	–
C. affine	–	–	90.4	105.2	253.7	741.0	263.5
Skeletonema costatum	101.3	233.7	255.4	595.8	133.3	296.4	38.8
Dinophycea							
Prorocentrum triestinum	1857.3	25342.2	46238.4	11170.5	71136.6	9056.6	3595.0
P. minimum	–	–	–	–	–	10.5	30.2
Scrippsiella trochoidea	259.3	211.2	289.0	297.9	237.1	296.4	80.5
Protoperidinium cerasus	50.8	189.2	90.5	–	–	–	–
Chlorophycea							
Euglena sp.	–	–	–	–	–	–	35.2

(–) Absent.

September-early October, this species exhibited another minor peak with nearly similar physical conditions (density $> 3 \cdot 10^6$ cells l^{-1}), but in contrast, nitrate remarkably higher (around 7.5 μmol l^{-1}). The spring bloom reported here, in agreement with previous records, occurred with thermo-haline stratification of the water column and low-surface nutrient concentrations. However, its peak occurred with relatively lower temperature and salinity. The data point to the importance of stabilization of the water column, rather than nutrients as a pre-requisite factor in development of red tide blooms in the harbour. According to Margalef *et al.* (1979), the conditions favouring the growth of a dinoflagellate population are relatively well defined. The dominance of flagellates with stagnation of water masses and low/or high nutrient levels are reported at other sites (Silva, 1985; Edler & Olson, 1985; Cohen, 1985). The correlations between the surface nutrient levels and the counts of *P. triestinum* between 3 and 11 April showed a significant correlation with nitrate ($r = 0.77$, $p < 0.05$, $n = 8$, Anova), while less significant correlations were found with nitrite ($r = 0.51$, $p > 0.05$), phosphate ($r = 0.52$, $p > 0.18$) and silicate ($r = 0.66$, $p > 0.05$). The empirical equations applied are:

$$\begin{aligned}\text{Counts of } P.\ triestinum &= 54997686 - 1.2 \cdot 10^7.[NO_3] \\ &= 44648579 - 3.1 \cdot 10^7.[NO_2] \\ &= 43999639 - 6274823.[PO_4] \\ &= -4.4 \cdot 10^7 + 9740814.[SiO_4]\end{aligned}$$

Although benthic cysts of *P. triestinum* have not yet been reported and no vegetative cells were released in a culture experiment from bottom mud at any of the tempera-

Table III Surface water temperature, counts of *P. triestinum* (cells l^{-1}) and the bloom index (BI)* calculated in the Eastern Harbour during 12 March and 8 April 1993.

Date	*T°C*	*Cells* l^{-1}	*BI*
March			
12	18.0	60	$0.84 \cdot 10^{-4}$
14	18.2	155	$0.22 \cdot 10^{-3}$
16	18.4	180	$0.25 \cdot 10^{-3}$
18	18.6	$11.6 \cdot 10^3$	0.02
23	16.2	410	$0.57 \cdot 10^{-3}$
26	17.6	$3.4 \cdot 10^3$	$0.48 \cdot 10^{-2}$
28	17.6	$3.9 \cdot 10^3$	$0.56 \cdot 10^{-2}$
April			
1	18.4	$18.9 \cdot 10^3$	$0.03 \cdot 10^{-2}$
2	18.6	$125.3 \cdot 10^3$	0.18
3	18.8	$4.1 \cdot 10^6$	5.63
4	19.0	$18.6 \cdot 10^6$	26.25
5	19.8	$25.3 \cdot 10^6$	35.62
6	19.9	$46.2 \cdot 10^6$	65.0
7	18.3	$11.1 \cdot 10^6$	15.7
8	19.0	$71.1 \cdot 10^6$	100

*$\text{BI} = \dfrac{N_{it}}{N_{i\max}} \times 100$, see text

tures examined between 9 and 25°C (Yamochi and Joh, 1986), a significant correlation was found between the bloom index (BI) and surface water temperature for the period from 12 March to 8 April (Table III) ($r = 0.58$, $p < 0.05$, $n = 15$, Anova), clearly indicating temperature to be a crucial environmental factor controlling the occurrence of *P. triestinum* in the harbour. The equation applied is:

$$\mathrm{BI} = -331.802 + 18.905.\ T°\mathrm{C}$$

The bloom index (BI) was calculated as follows;

$$\mathrm{BI} = (N_{it}/N_{i\max}) \cdot 100$$

where N_{it} is cell density of *P. triestinum* (*i*) at the time *t*, $N_{i\max}$ is the maximum cell density of *P. triestinum* (*i*) during the period. This conclusion could be supported also by the significant correlation ($r = 0.35$, $p < 0.5$, $n = 81$, Anova) between the counts of *P. triestinum* and temperatures measured in the Eastern Harbour during 1991 (Labib 1994 a,b). Salinity was also significantly correlated with the counts ($r = 0.32$, $p < 0.05$, $n = 81$, Anova). The equations applied are:

$$\begin{aligned}\text{Counts of } P.\ triestinum &= -2882855 + 144745.6.\ T°\mathrm{C} \\ &= 12898635 - 326381.\ \mathrm{S}‰.\end{aligned}$$

Other conditions accelerating the development of the bloom could include: (1) the ability of *P. triestinum* to follow a vertical migration (Anderson & Stolzenbach, 1985; Labib, 1990), where the most cited advantage is that of access to nutrients below the depleted surface layer in the stratified water; (2) the high concentration of ammonia (6.5 μmol l^{-1}) and low oxygen (3.5–4.6 ml l^{-1}) above the bottom facilitating the release of sediment metals, vitamin B_{12} and organic chelators into the water column (Kurata, 1969; Honjo, 1974; Hoshika *et al.*, 1978; Anderson & Morel, 1987); (3) the light wind (1.8 m s^{-1}) which persisted for several days.

The relative growth constant (k) and the doubling time (t_D) of *P. triestinum* during the period 1–8 April was calculated from changes in cell counts. The equation applied is:

$$\begin{aligned}k &= Ln\ N_1 - Ln\ N_0/(t_1 - t_0) \\ t_D &= Ln\ 2\,/\,k\end{aligned}$$

where N_1 and N_0 are numbers of *P. triestinum* at time t_1 and t_0. The value of k was highest (3.46 d^{-1}, t_D 0.2 days) just prior to the massive occurrence of the bloom between 2–3 April, reflecting its rapid development. The k value was reduced sharply, varying between 0.31 and 0.60 d^{-1} (t_D 2.24 and 1.16 days) as the bloom progressed between 4–6 April. This value is significantly lower than that calculated by Fukazawa *et al.*, 1980 (0.70 d^{-1}) for *P. triestinum* in a culture experiment. Factors such as sinking, water exchange with the adjacent Mediterranean Sea and grazing must be considered. On the other hand, the value of (t_D) between 3–4 April (0.45 days) is almost the same (0.42–0.54 days) as that recorded in a unialgal culture of *P. triestinum* by Karnetz (1983).

References

Anderson, D. M. and Morel, F. M. (1987) Copper sensitivity of *Gonyaulax tamarensis*. *Limnol. Oceanogr.*, **23**: 283–295.

Anderson, D. M. and Stolzenbach, D. K. (1985) Selective retention of two dinoflagellates in a well mixed estuarine embayment: the importance of diel vertical migration and surface avoidance. *Mar. Ecol. Prog. Ser.*, **25**: 39–50.

Cohen, R. R. H. (1985) Physical processes and the ecology of a winter dinoflagellate bloom of *Katodinium rotundatum*. *Mar. Ecol. Prog. Ser.*, **26**: 135–144.

Edler, L. and Olsson, P. (1985) Observation on diel migration of *Creatium furca* and *Prorocentrum micans* in a stratified bay on the Swedish west coast. In: *Toxic Dinoflagellates*. (editors Anderson, *et al.*), Elsevier, New York pp. 195–200.

Fukazawa, N., Ishimaru, T., Takahashi, M. and Fujita, Y. (1980) A mechanism of red tide formation. 1. Growth rate estimated by DCMU-induced fluorescence increase. *Mar. Ecol. Prog. Ser.*, **3**: 217–222.

Halim, Y. (1960) *Alexandrium minutum*, n. gen., n. sp., dinoflagellate provoquant des eaux rouges. *Vie et Milieu*, **11**: 102–105.

Honjo, T. (1974) Studies of the mechanisms of red tide occurrence in Hakata Bay. Environmental conditions during the blooming season and essential factors of red tide occurrence. *Bull. Tokai Reg. Fish. Res. Lab.*, No. 79, 77–121.

Hoshika, A., Takimura, O. and Shiozaka, T. (1978) Vertical distribution of particulate manganese and iron in Beppu Bay. *J. Oceanogr. Soc. Japan*, **34**: 261–264.

Iizuka, S. (1976) Succession of red tide organisms in Omura Bay, with relation to water pollution. *Bull. Plank. Japan*, **23**: 25–35.

Karentz, D. (1983) Patterns of DNA synthesis and cell division in marine dinoflagellates. *Protozool.*, **30**: 581–588.

Kurata, A. (1969) Vitamin B_{12} in the bottom mud. *J. Oceanogr. Soc. Japan*, **34**: 261–264.

Labib W. (1990) Ecological studies of the phytoplankton dynamics at Aburatsubo Bay, Kanagawa, Japan Ph. D. thesis, Tokyo University, 195 pp.

Labib, W. (1994 a) Ecological study of spring-early summer phytoplankton blooms in a semi-enclosed estuary. *Chemistry and Ecology*, **9**: 75–85.

Labib, W. (1994 b) Massive algal pollution in a highly eutrophic marine basin, Alexandria (Egypt). The 4th Conf. *Environmental Protection is a Must*, Alexandria, 181–194.

Labib, W. and Hussein, M. (1994) Water discoloration in Alexandria, Egypt, April 1993. II. Factors controlling the dissipation of the dinoflagellate *Prorocentrum triestinum* red tide bloom. *Alexandria Science Exchange*, **15**: 481–494.

Margalef, R., Estrada, M. and Blasco, D. (1979) Functional morphology of organisms involved in red tides, as adapted to decaying turbulence. In: *Toxic Dinoflagellate Blooms* (Editors Taylor and Seliger), Elsevier, New York, pp. 89–94.

Silva, E. S. (1985) Ecological factors related to *Prorocentrum minimum* in Obidos Lagoon (Portugal). In: *Toxic Dinoflagellates Blooms* (Editors Anderson, *et al.*), Elsevier, New York, 251–256.

Strickland, J. D. and Parsons, T. R. (1972) *A Practical Handbook of Sea Water Analysis*. 2nd ed. *Bull. Fish. Res. Bd. Canada*, No. **167**: 310 pp.

Sultan, H. A. (1975) Preliminary investigation in the primary production of marine phytoplankton of the Egyptian Mediterranean coast of Alexandria region. M.Sc. Thesis, Faculty of Science, Alexandria University, 151 pp.

Ultermöhl, H. (1958) Zur vervollkommnug der quantitativen phytoplankton Methodik. *Limnol. Oceanogr.*, **9**: 1–38.

Yamochi, S. and Joh, H. (1986) Effect of temperature on the vegetative cell liberation of seven species of red tide algae from the bottom mud in Osaka Bay. *J. Oceanogr. Soc. Japan*, **42**: 226–275.

Zahgloul, F. A. and Halim, Y. (1992) Long-term eutrophication in a semi-closed bay: the Eastern Harbour of Alexandria. *Science of the Total Environment*, 727–735.